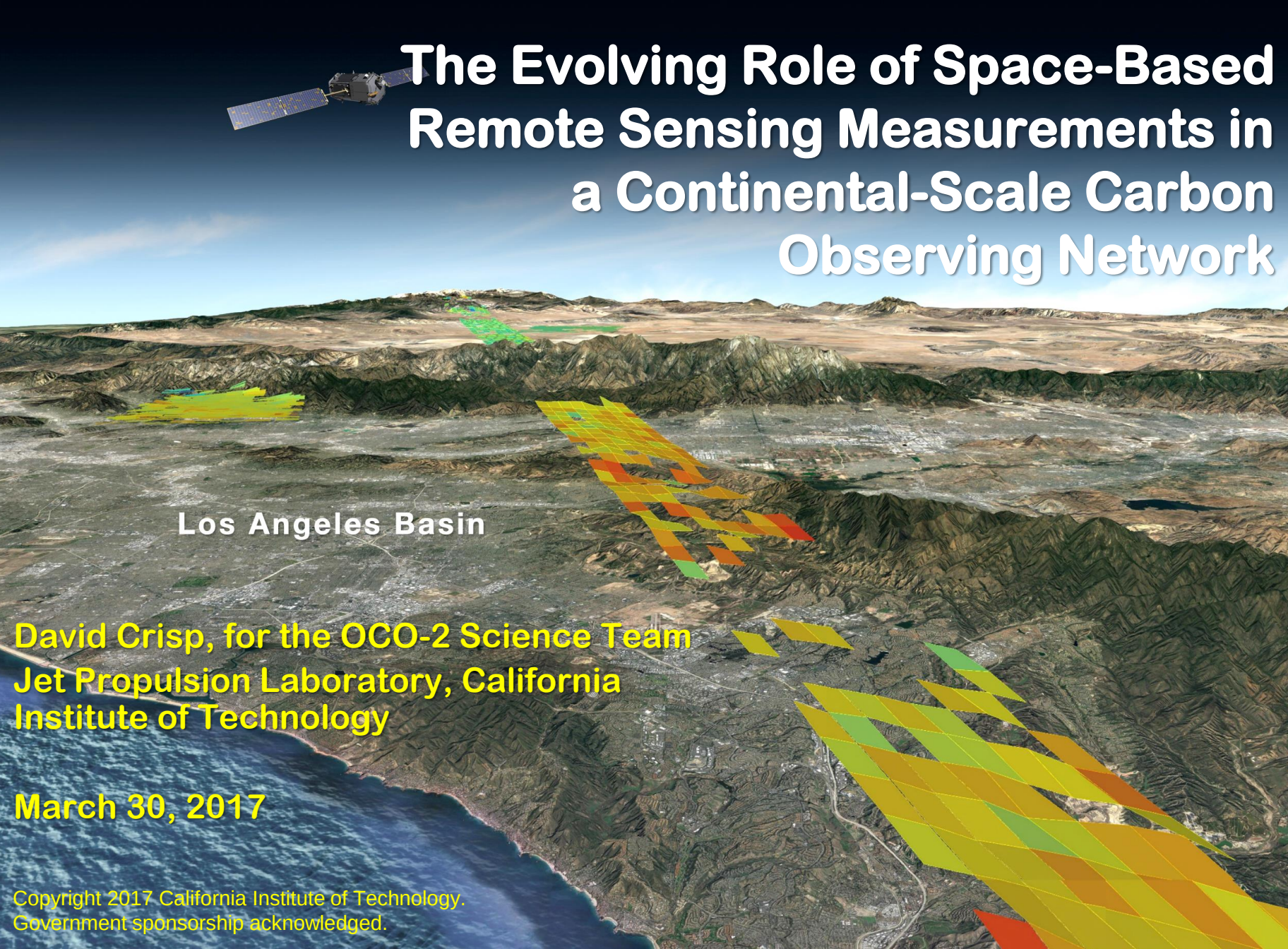


The Evolving Role of Space-Based Remote Sensing Measurements in a Continental-Scale Carbon Observing Network

David Crisp, for the OCO-2 Science Team
Jet Propulsion Laboratory, California Institute of Technology

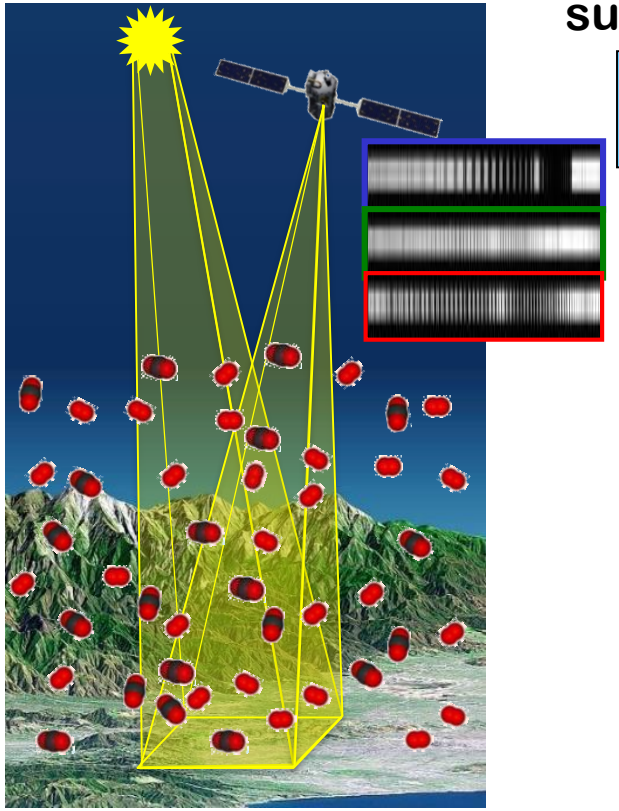
March 30, 2017

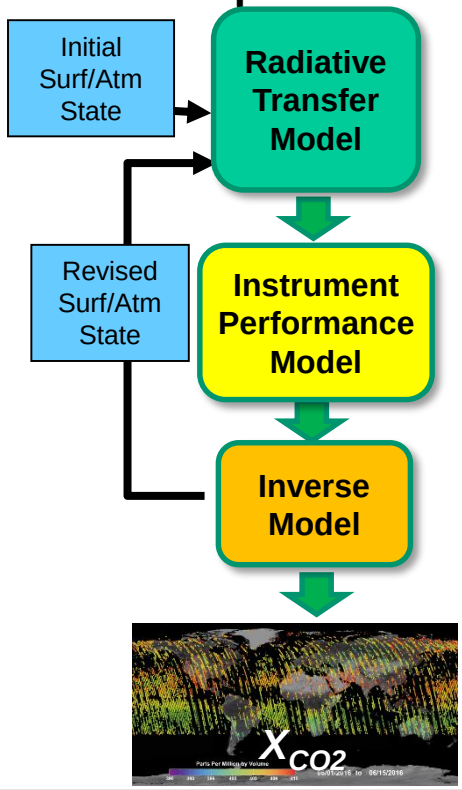
Measuring CO_2 from Space

- **Record** spectra of CO_2 and O_2 absorption in reflected sunlight

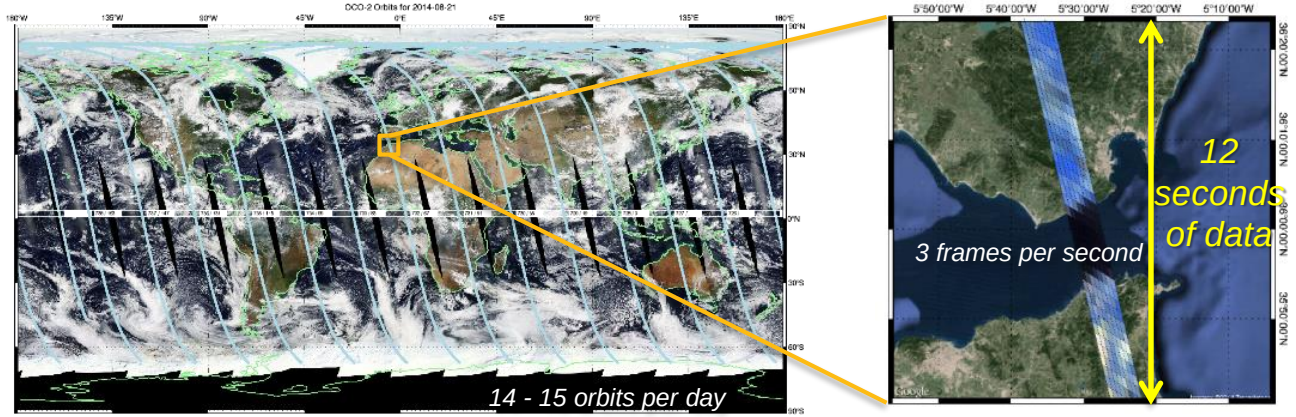
Retrieve variations in the **column averaged CO_2 dry air mole fraction, X_{CO2}** over the sunlit hemisphere

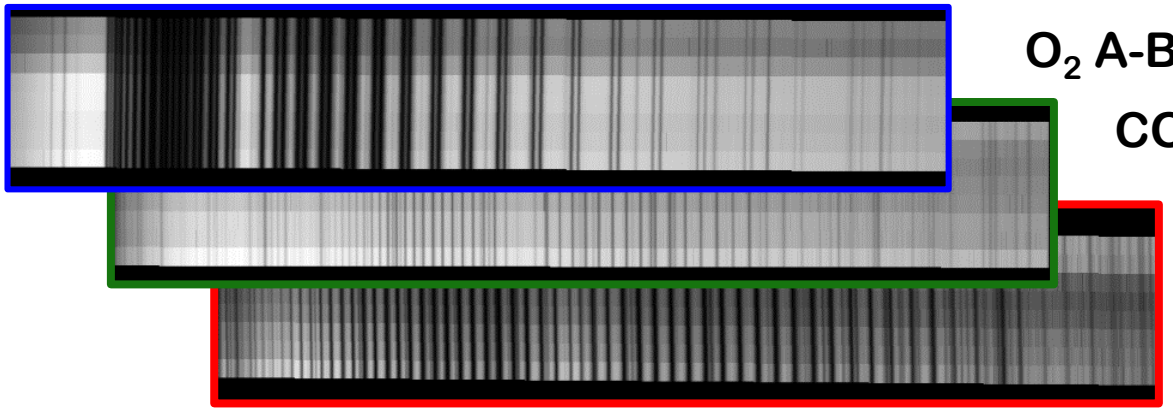
Validate measurements to ensure X_{CO2} accuracy of 1 ppm (0.25%)





OCO-2 Sampling Approach





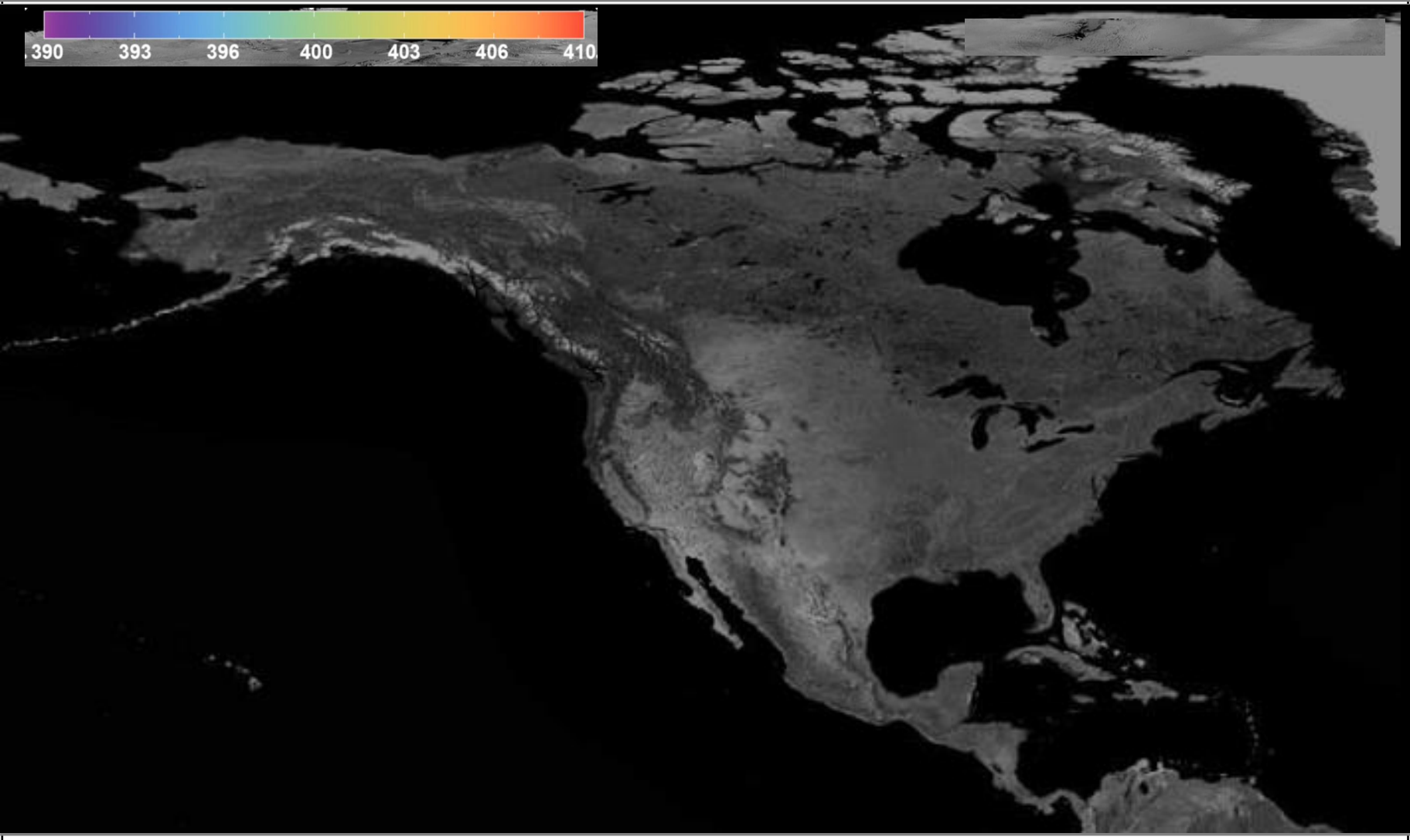
O_2 A-Band

CO_2 1.61 μm Band

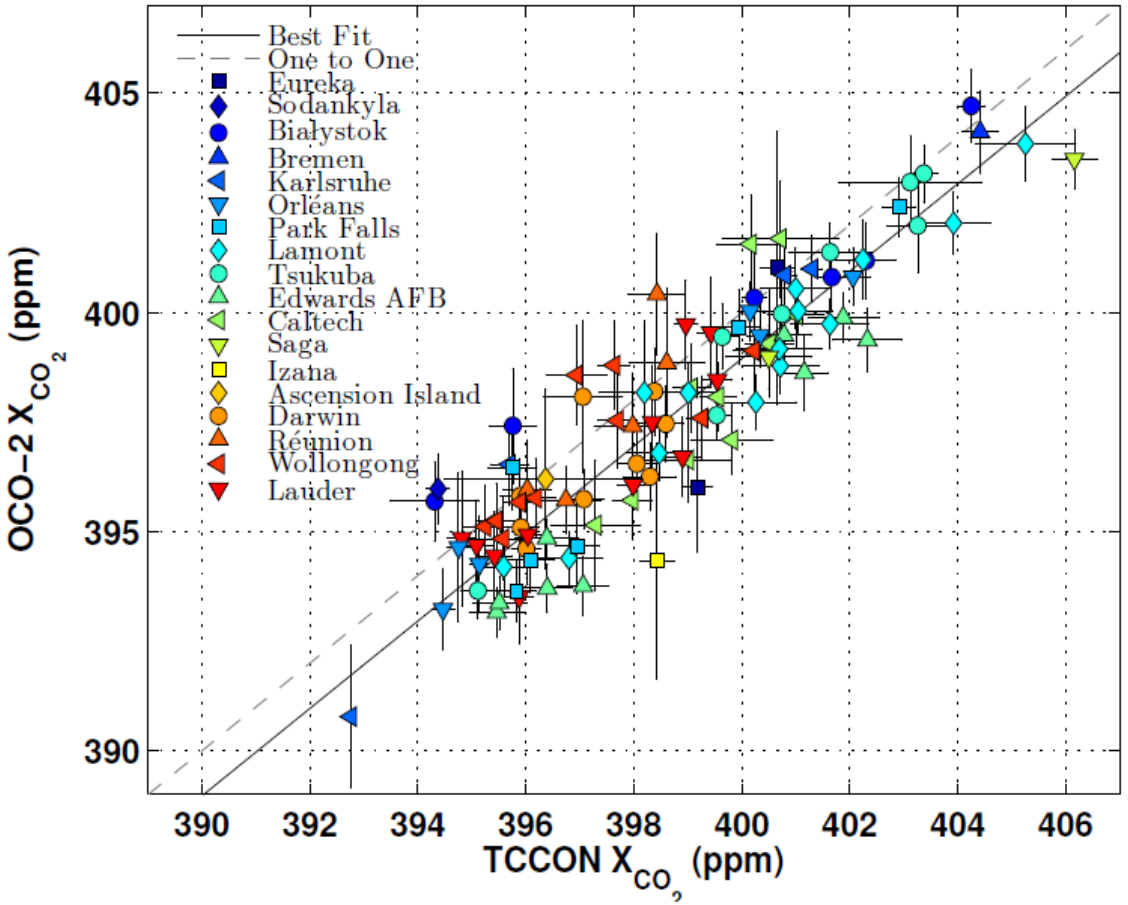
CO_2 2.06 μm Band

The OCO-2 instrument collects 24 soundings each second as it flies over the sunlit hemisphere of the Earth, yielding almost 1 million soundings each day

A Quick Look at the OCO-2 Prime Mission



Comparison of TCCON and OCO-2 X_{CO2}



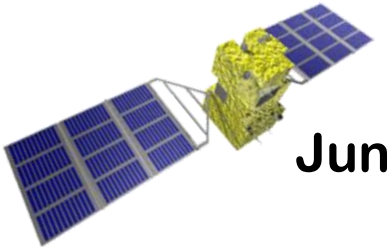
Comparisons with the Total Carbon Column Observing Network (TCCON) stations are being used to identify and correct biases in target observations.

After applying a bias correction

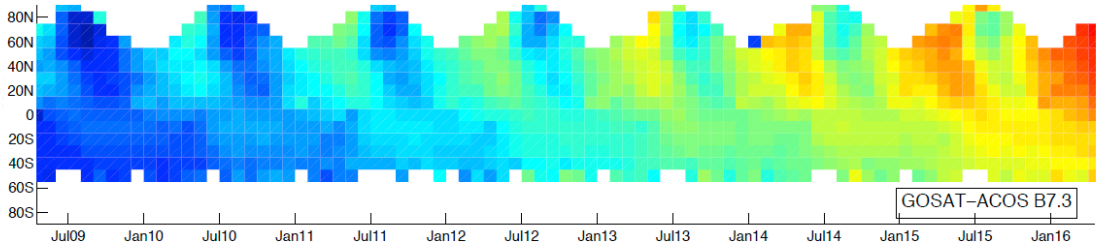
- Global bias is reduced to < 0.5 ppm
- Station-to-station biases reduced to ~1.5 ppm

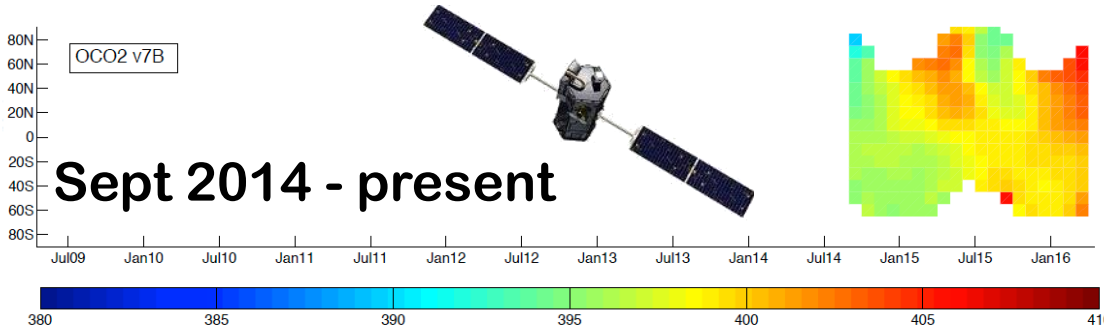
Wunch et al. (2016)

ACOS/GOSAT B7.3, and OCO-2 v7 XCO2



June 2009 - present

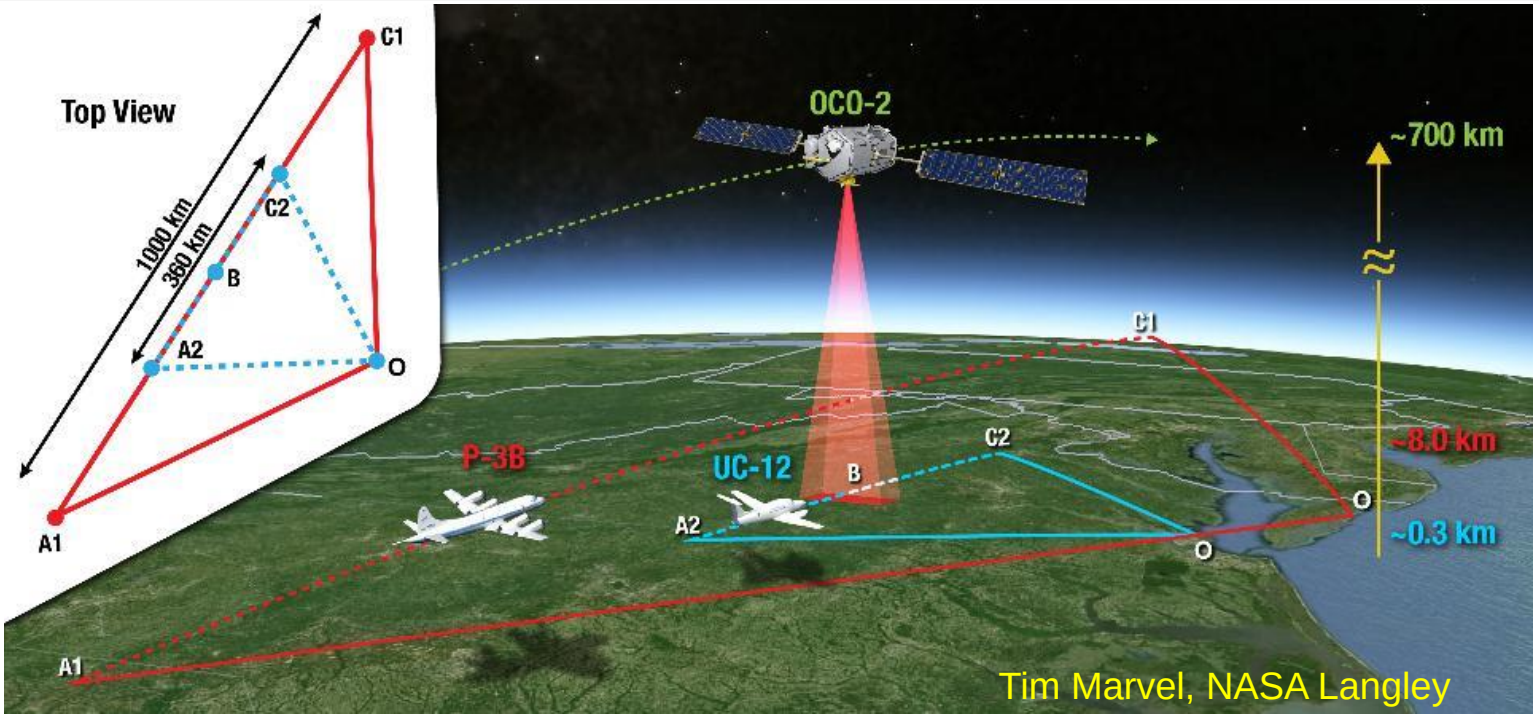




TCCON and other standards have been used to cross validate OCO-2 and GOSAT X_{CO2} to extend the climate data record

- Differences between GOSAT-ACOS B7.3 and OCO2 v7r are within ±1 ppm for overlap regions

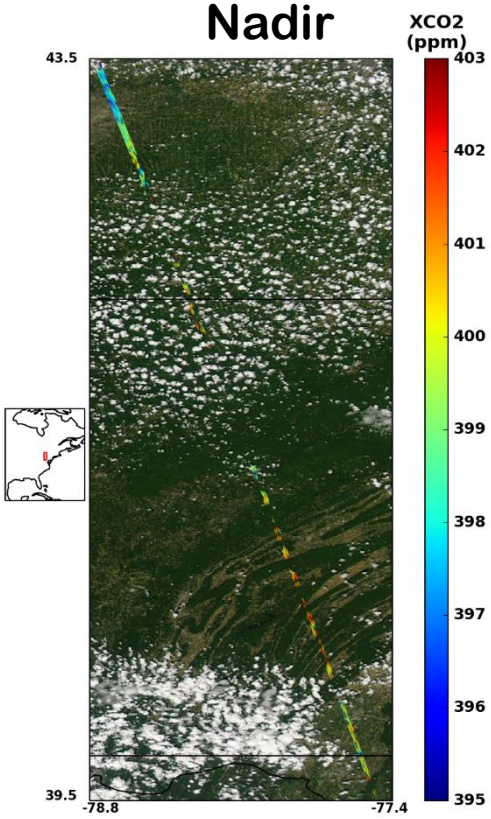
OCO-2 under-flights by ACT-America



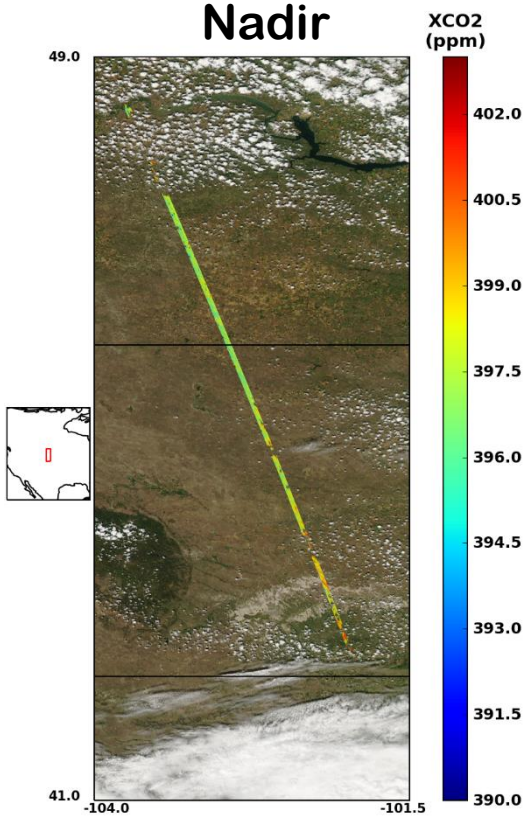
- Measure much of the atmospheric CO_2 column at < 20km horizontal resolution across 100's of km below OCO-2.
  - Also measure partial column X_{CO2}, aerosols and clouds with lidar.
- Compare spatial variability in airborne CO_2 to OCO-2 CO_2. Evaluate OCO-2 ability to capture tropospheric CO_2 variability along-track.

Summer 2016 ACT-America Campaign

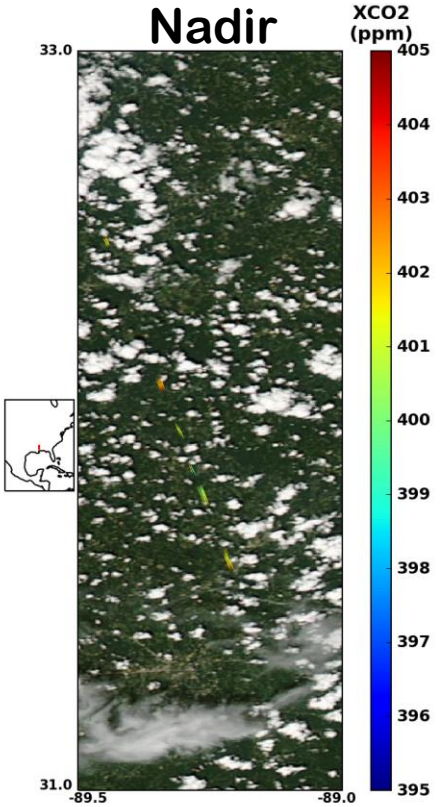
27 July, 2016: Mid-Atlantic Orbit 11016, Nadir



5 August, 2016: Mid-West Orbit 11148, Nadir

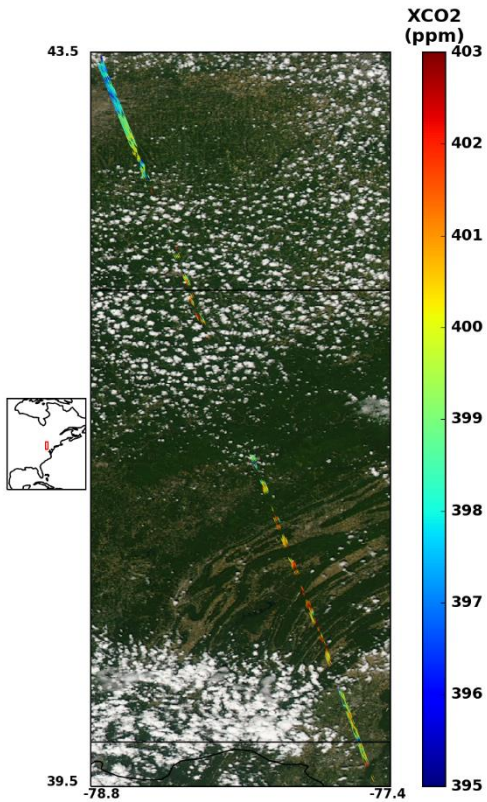


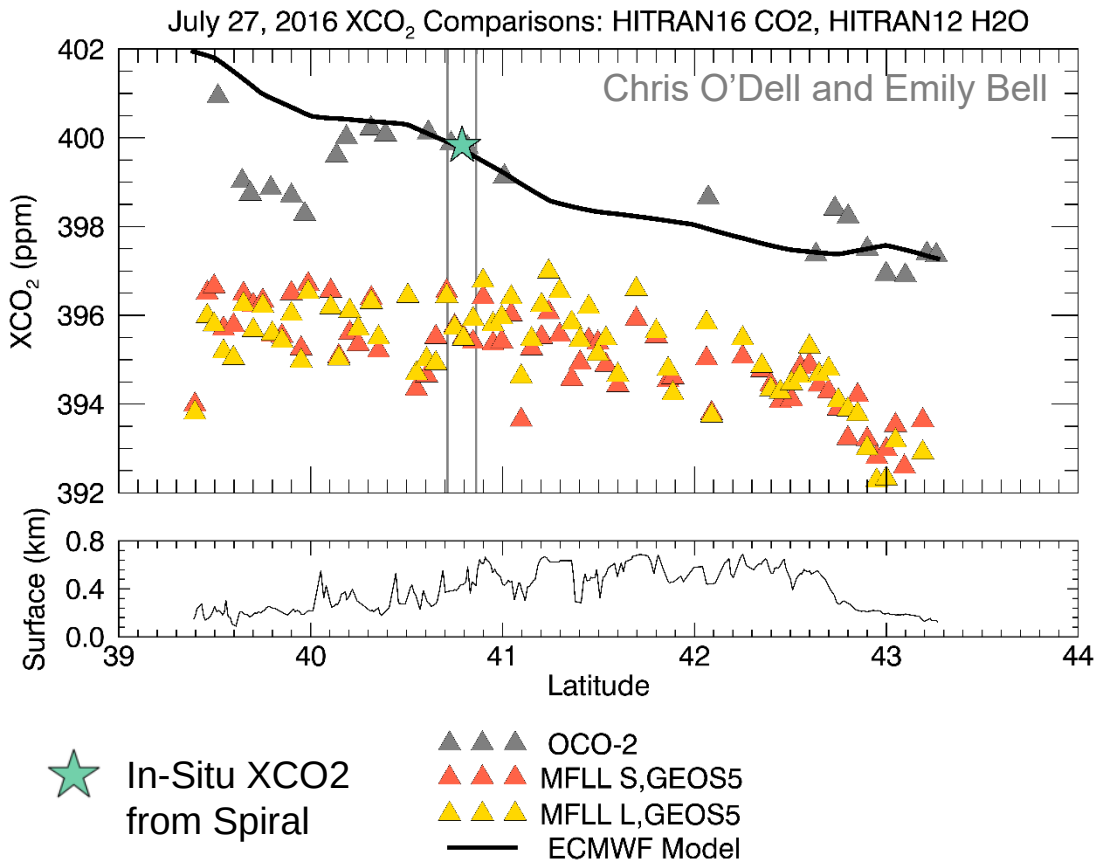
27 August, 2016: South Orbit 11468, Nadir



Chris O'Dell and Emily Bell

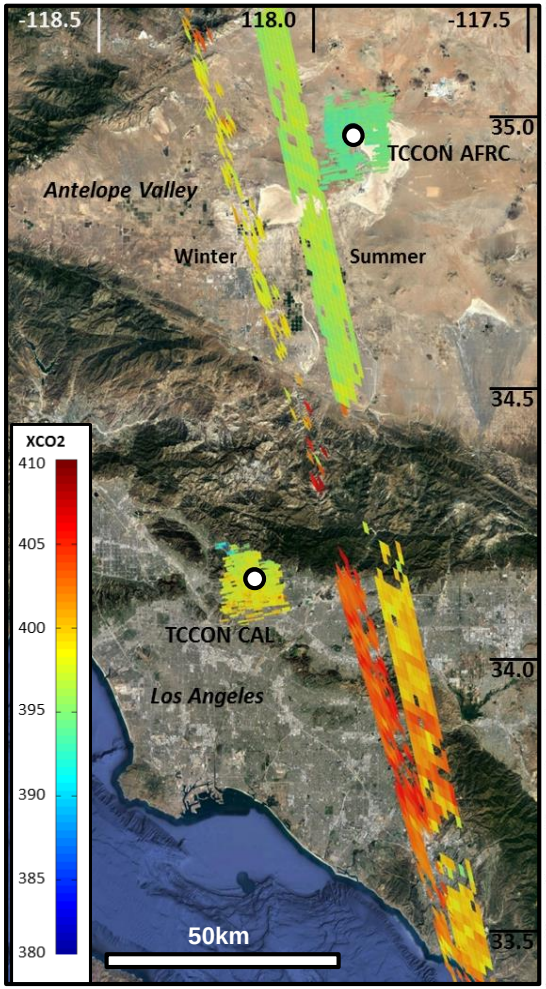
Comparison of X_{CO2} Estimates

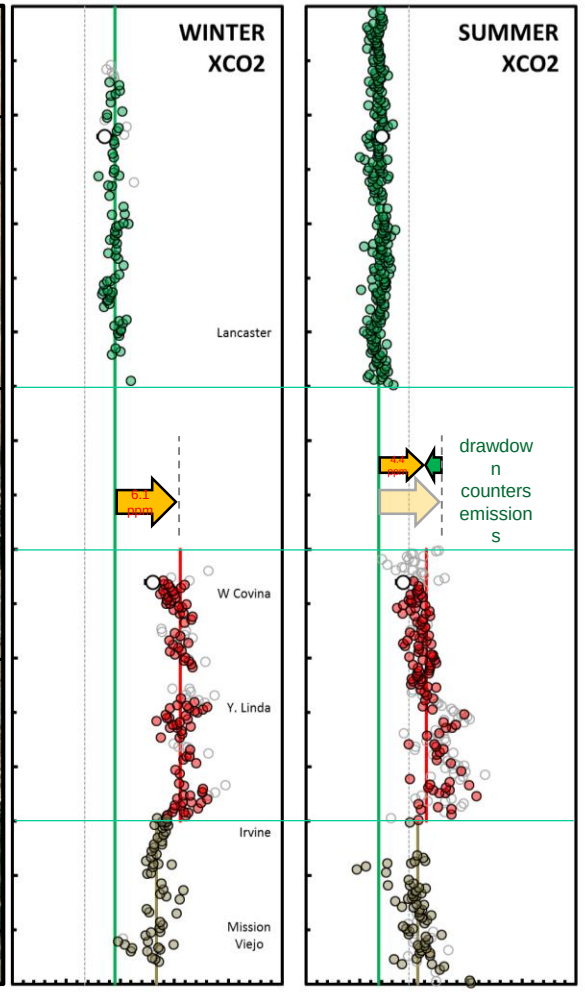




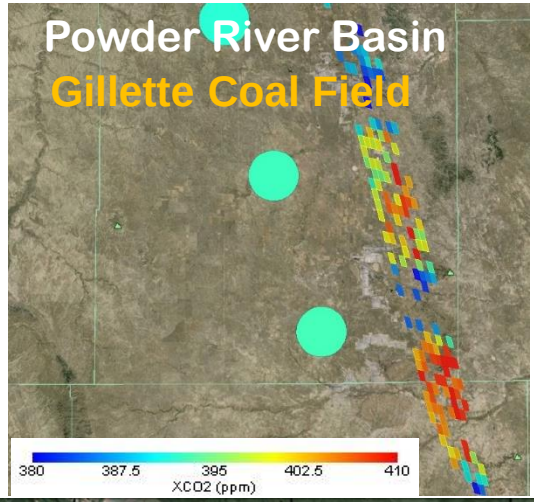
- All sensors capture CO_2 decrease on north end of the flight track (western NY).
- Fair weather cumulus in northern PA/southern NY preclude OCO-2 full column X_{CO2}
- Source of offset in MFLL partial column estimates is under investigation

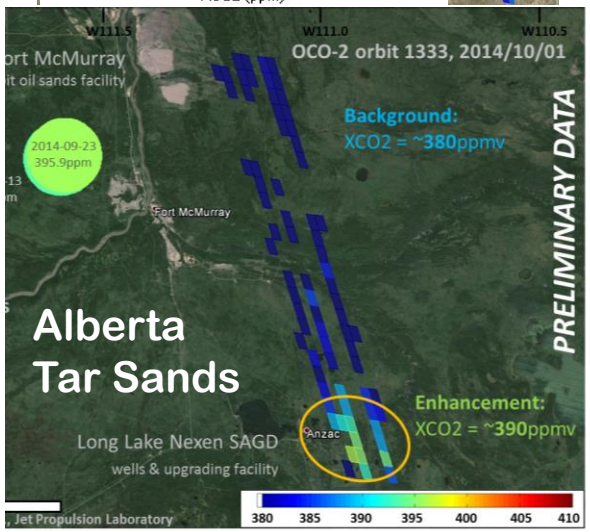
Localized Sources





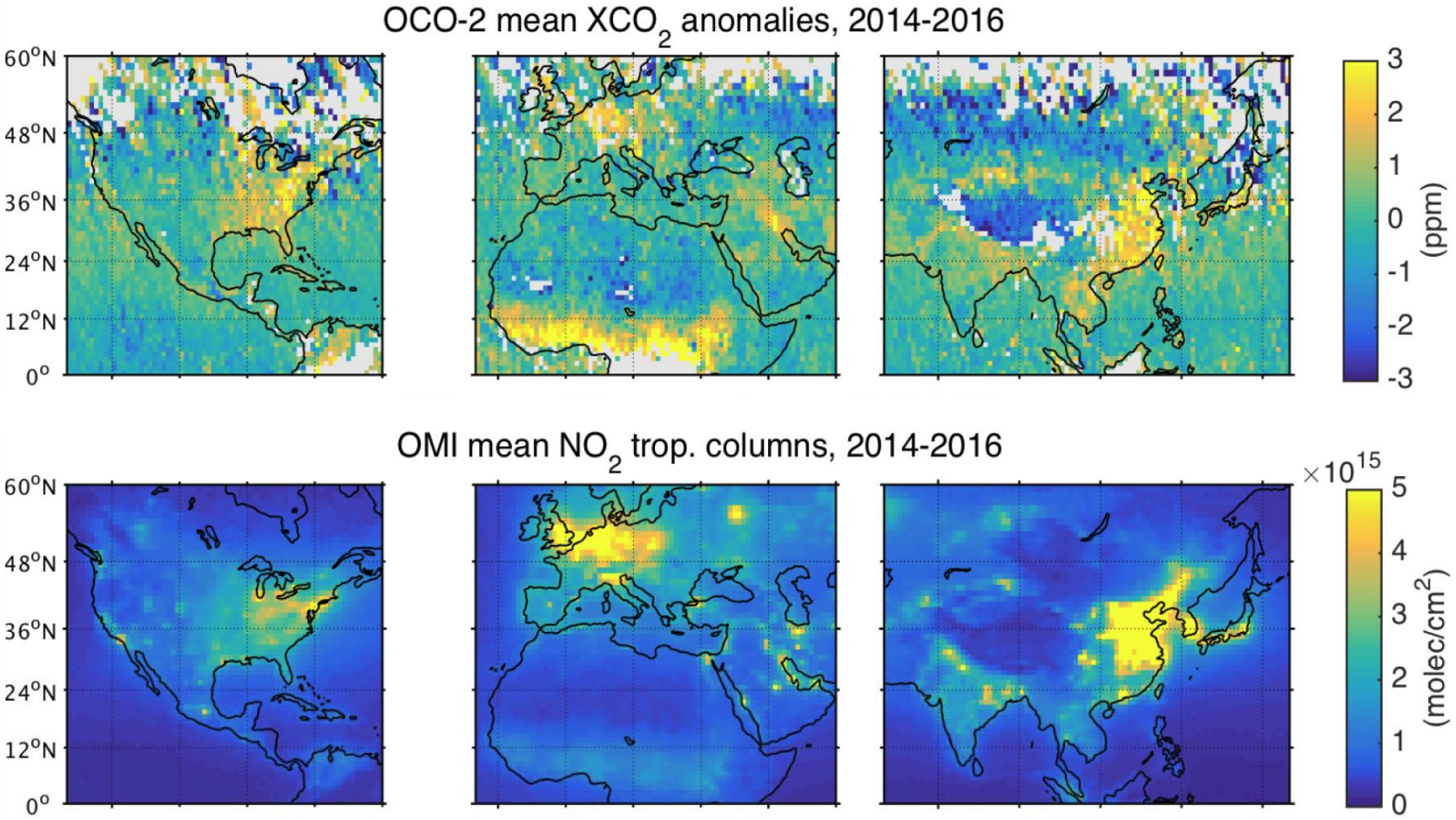
Los Angeles Basin





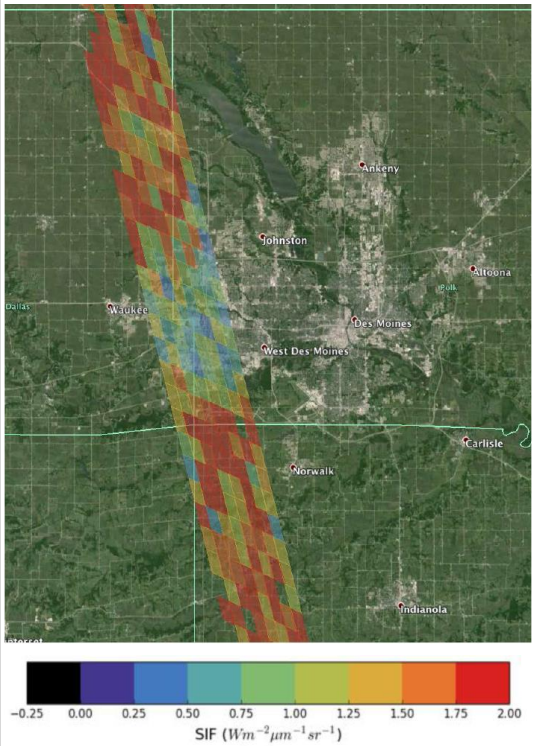
Florian Schwandner et al.(Submitted 2017)

Anthropogenic Emissions

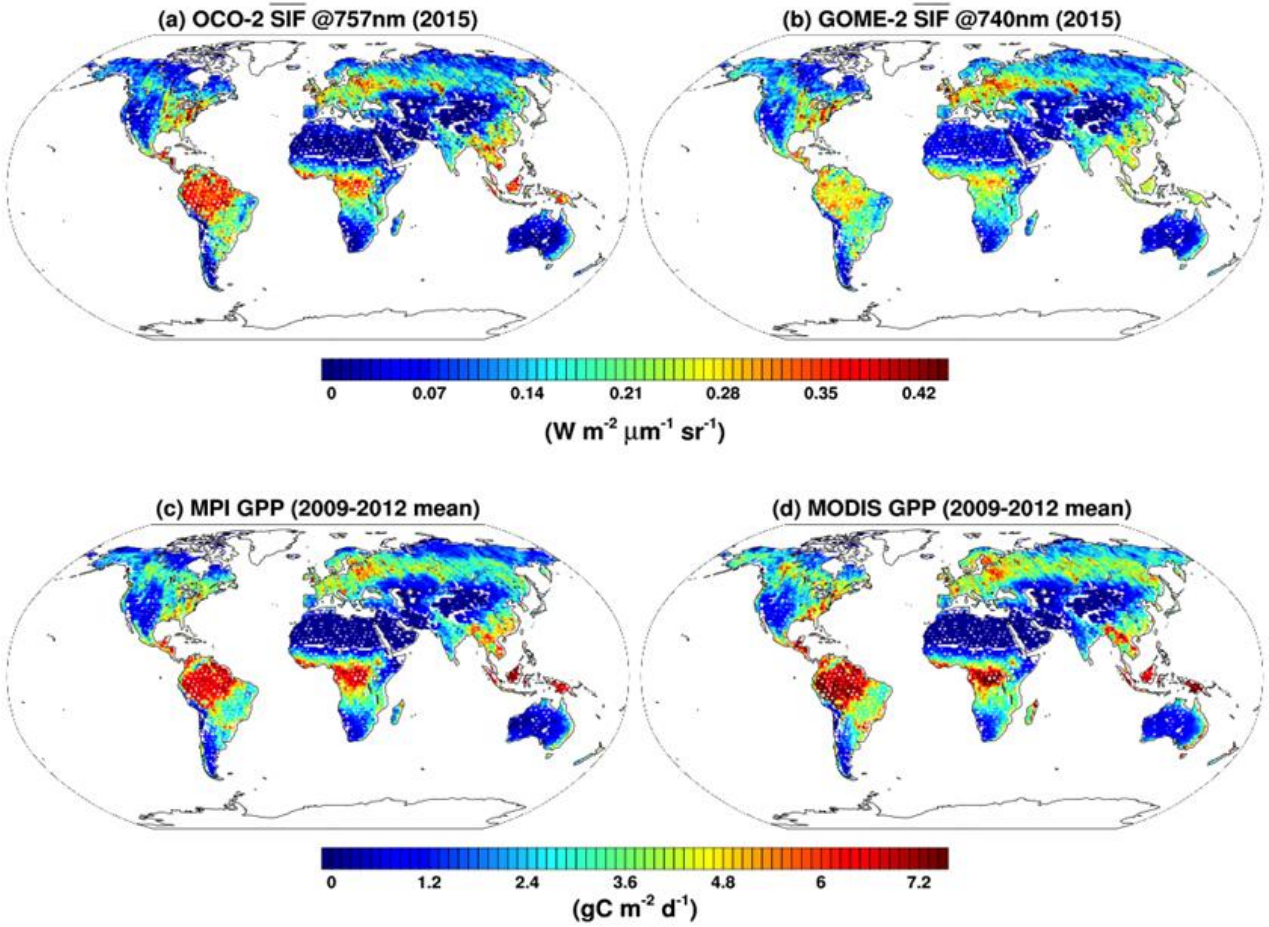


Janne Hakkarainen et al. GRL (2016)

Solar Induced Chlorophyll Fluorescence (SIF)



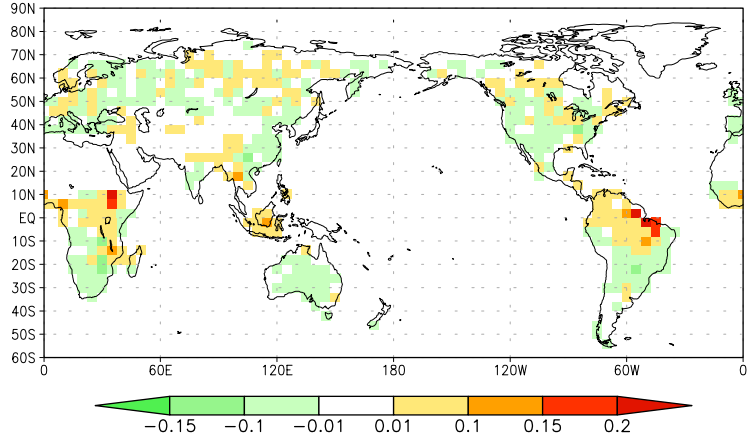
OCO-2 SIF over Des Moines, Idaho



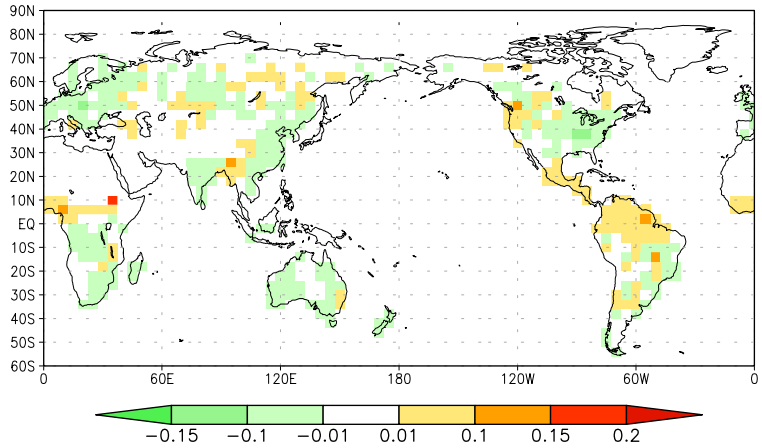
Ying Sun et al. (submitted 2017)

2015 El Niño and 2011 La Niña annual biosphere fluxes and their differences

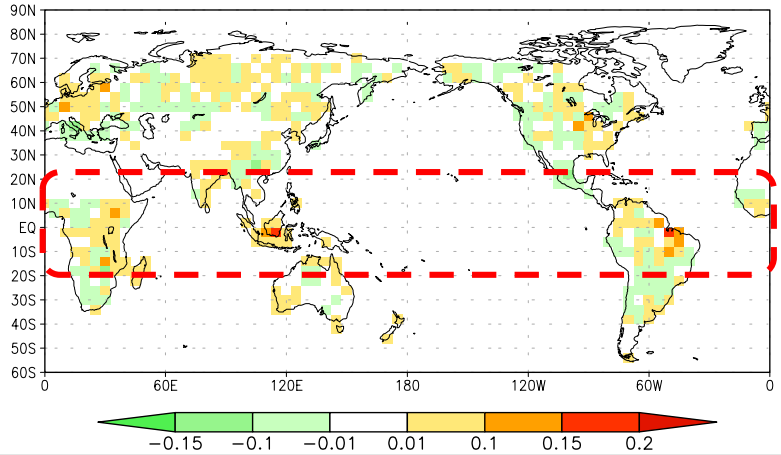
2015 (GtC/yr)



2011 (GtC/yr)



2015- 2011 (GtC/yr)



Red: release CO_2 into atmosphere

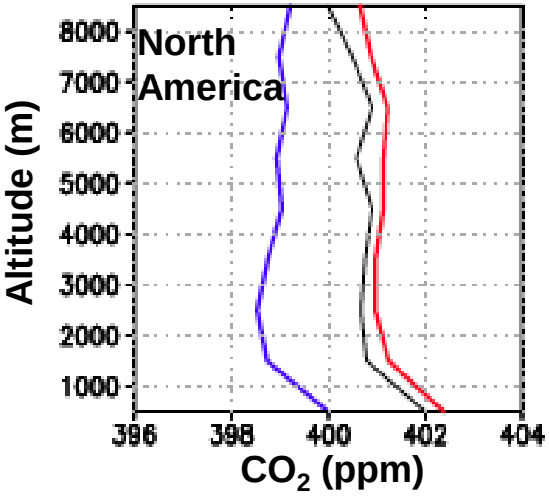
Green: absorb CO_2 from atmosphere

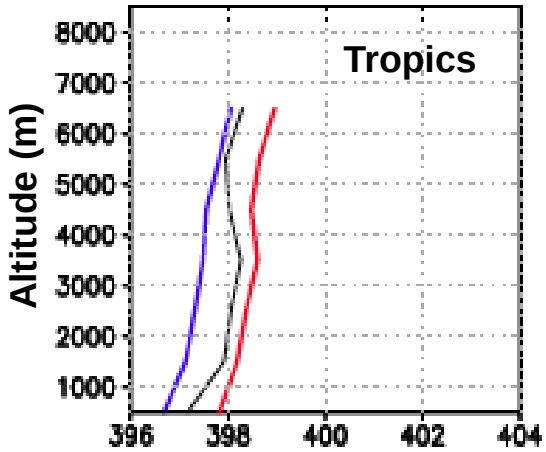
- **The most significant impact of 2015 El Niño on biosphere carbon fluxes is the increase of CO_2 release from the tropics**

Junjie Liu et al. (Submitted 2017)

Validating Regional Flux Changes

Aircraft vs OCO-2

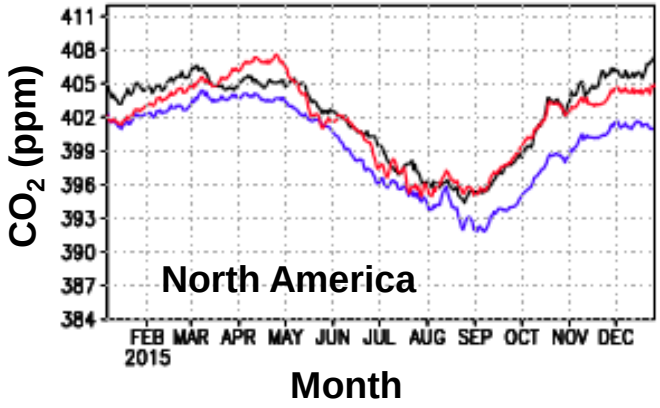


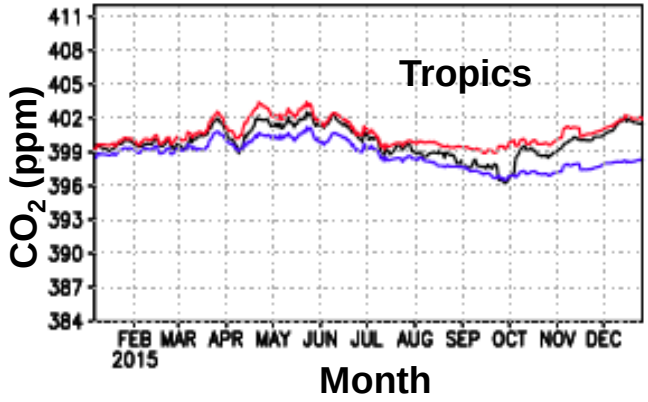


Junjie Liu et al. compare modeled profiles derived in their studies to aircraft and modeled in situ surface values to flask in situ measurements

- Blue: model prior
- Red: model posterior
- Black: in situ observation

Surface Flask vs OCO-2





Junjie Liu et al. (Submitted 2017)

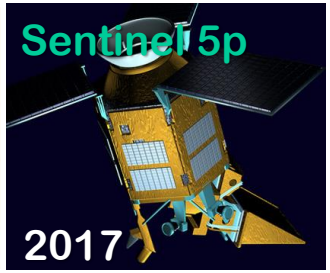
Evolving Carbon Measurement Capabilities

PAST

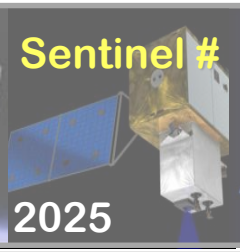
- TanSat Successfully Launched on 22 Dec 2016
- NASA Earth Ventures GeoCarb Selected
- CNES MicroCarb Approved for Implementation

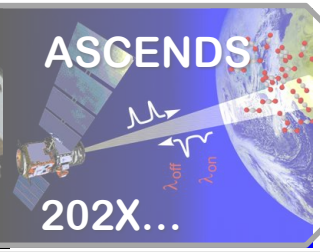
PRESENT

NEAR FUTURE



LATER





Summary

- OCO-2 was successfully launched on 2 July 2014, and started its first extended mission on October 16, 2016
  - Its 3-channel spectrometer is now returning 1000s of full-column estimates of X_{CO2} over North America each day
  - These products are being validated against TCCON and other standards to assess their accuracy
    - Small (< 1 ppm), spatially-coherent biases are still posing problems, but are being addressed with algorithm updates
  - ~30 months of data have been delivered to the Goddard Earth Sciences Data and Information Services Center (GES-DISC)

    http://disc.sci.gsfc.nasa.gov/OCO-2
- A closer collaboration among the space-based, airborne, and ground-based elements of the carbon-observing network would facilitate the detection and characterization of small-amplitude biases in the space-based products.

Thank You for Your Attention

Questions?